To develop an economic management system to control witches' broom disease of cocoa in a number of cocoa growing environments.

Objective

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There were subsidiary objectives :
1. To study systematically infection dynamics of witches' broom disease relative to time (both seasons and years) with respect to the critical environmental factors.

2. To examine and evaluate the reaction of the pathogen to available systemic, protective and eradicative fungicides including the application to the soil and the effect on basidiocarp development of brooms sprayed when green.

Methods for comparative epidemiology experiment

A protocol was established for the recording of data so that results from different sites would be directly comparable. Initially eight sites (two in Brazil, two in Colombia, two in Ecuador, one in Trinidad and one in Venezuela) were planned to start in 1985, although local difficulties delayed some sites into late 1986.

Ten representative sample trees were chosen to form a plot within a plantation containing a minimum of 50 trees. Five units were selected for the recording of vegetative and flower cushion activity in each tree. Each vegetative unit contained a minimum of 10 healthy growing points, and 2-weekly recordings made of the number of extending new shoots (flushes), the number of flush leaves, and the numbers of various types of infection. Five 1.0 m lengths of branch were examined at 2 weekly intervals and the number of active flower cushion and active cushions with open flowers recorded, together with numbers of various types of cushion infection. Pods were recorded on the marked branches as they set and developed so that detailed information was available for a part of the harvest. Presence of open, turgid basidiocarps was registered on vegetative brooms, infected cushions, and diseased pods at different positions in the tree and the soil beneath the trees.

Meteorological data were available from stations established near the designated plots, covering air temperature, relative humidity, rain, and surface wetness.

Methods for chemical evaluation

Guidelines for experiments on evaluation of chemicals under controlled conditions and in the field were prepared. Experiments were conducted at a number of sites.

Seedlings to be used for controlled environment tests were cut back before inoculation with basidiospore suspensions, in order to stimulate uniform shoot growth. Chemicals were applied as soil drenches or aerial sprays, before or after inoculation. Evaluation was by the presence or absence of a broom, and the level of necrosis. Developing pods were protected from natural infection using plastic bags and were inoculated with basidiospore suspensions when 6 weeks old. Infection was assessed directly by the presence or absence of necrosis after 3 months.

Field plots were of 49 trees with one border row and 5 x 5 tree experimental area. Three replicates of a minimum of five treatments were made and chemicals applied either as a soil drench or sprayed by motorised mistblower.

Results for comparative epidemiology experiment

■ Sources of inoculum

Induction of basidiocarp production on brooms was related to the number of days with rain. A distinct dry season occurred in most sites. At the end of the dry season an average of 27 days with rain were required before any basidiocarps were formed on new first year brooms, but only 19 days for second year brooms. Vegetative brooms placed in the canopy produced an average of 12 basidiocarps in 1986 and 8 in 1987, and were active for at least 20 weeks. Vegetative and cushion brooms were more important sources of inoculum than diseased pods and activity was greatly reduced, in some sites eradicated, by placing them on the ground in leaf litter. The potential inoculum period was clearly defined in all sites and little change occurred between years. Peaks of inoculum pressure within the production period were more difficult to explain, with timing and intensity of rain the most important variable.

Vegetative infection

Some growing shoots were not exposed to inoculum, and the proportion that escaped infection varied between 83% (Trinidad) and 40% (Altamira). The amount of shoot growth by each bud in the period of inoculum production also varied. The mean number of new shoots per bud was a maximum of 1.75 in Ecuador and a minimum of 0.20 in Trinidad. The number of infections per bud in the various sites was directly related to the number of flushes exposed to inoculum.

■ Cushion infection

Cushion activity on the marked branches decreased between the first and second years in all sites, decreasing in most cases by a number equivalent to the number of cushions infected during the first year. The trees in the sites varied between 8 and 20 years in age, and the number of active cushions in the market branches decreased with age.

Not all cushions were active during the period of inoculum production. Intensity of cushion infection was related to the proportion of infections first expressed as brooms, which itself was related to the proportion of vegetative infections first expressed as swellings on petioles and stems rather than brooms.

■ Pod infection

Pod loss to disease was caused by more than one pathogen, three sites having three diseases and the rest only two.

True pod losses caused by *Crinipellis perniciosa* were difficult to calculate, but a clear incubation period of 10-12 weeks was found between infection and pod necrosis.

In all sites most pods were exposed to inoculum while at a susceptible stage of development, and direct losses varied between 10 and 45%. Pod infection was related more to the number of periods of surface wetness (due to rain) than to inoculum levels, which was not limiting in most sites. Pod production varied greatly between sites and decreased with tree age. The number of pods produced on the marked branches was directly related to the number of active cushions.

Results for chemical evaluation

Preliminary screens have highlighted two commercially available systemic fungicides which show promise. These are Bayfidan and Anvil, produced by Bayer AG and ICI Agrochemicals respectively. *Crinipellis perniciosa* is highly sensitive to both compounds *in vitro*, and good preventative and curative actions have been found with aerial sprays onto foliage and with soil drenches. The compounds are now under field trial using various regimes and methods of application mostly on mature trees.

Conclusions

The comparative Epidemiology Experiment has indicated several general characteristics of witches' broom epidemics. Inoculum is not generally a limiting factor during the period of basidiocarp production. The amount of host tissue available limits vegetative infection, although there is an effect of inoculum pressure on the types of infection produced on shoots and cushions. Rain, and rain-derived wetness control the onset and intensity of inoculum production, and also the amount of pod infection. Cushion infection may be causing cushion death, but cushion loss is certainly cumulative with age and thus reduces the potential for pod production. Control strategies must be aimed at reducing infection before cushion loss becomes significant. It may be possible to control pod and vegetative infection in old plantations, but cushion productivity may be so low that the control measures would not be economic.

Strategies for diseases control using fungicides must be based on knowledge of the timing of the main events in the epidemic. These events are now known for the sites in the Comparative Epidemiology Experiment. Active systemic fungicides have been found that can be soil applied if necessary. The regimes of application, combined with sanitation pruning in areas of high disease intensity, must now be refined before control recommendations can be extended to farmers. This work will soon be starting combined with a number of other experiments designed to provide fundamental information on the disease.

A very considerable volume of data remains to be analysed and this analysis will continue over the next 12-18 months.

Publications

1. IOCCC (1985) Report of 1st Workshop of International Witches'Broom Project
2. IOCCC (1985) Report of 2nd Workshop of International Witches'Broom Project
3. IOCCC (1986) Report of 3rd Workshop of International Witches'Broom Project
4. IOCCC (1987) Report of 4th Workshop of International Witches'Broom Project
5. IOCCC (1988) Description of the symptoms of Witches'broom disease of cocoa, caused by *Crinipellis perniciosa*, *Cocoa Growers' Bulletin* (in press).
6. Mc Quilken, M.P., Supriadi and Rudgard, S.A. (1989) Sensitivity of *Crinepellis perniciosa* to two triasole trials of fungicide *in vitro* and their effect on development of the fungus in cocoa, *Plant Pathology*, 38, (in press).
7. IOCCC (1989) Witches' Broom Disease of Cocoa in Tropical America : Comparative Epidemiology and Management. Monograph in preparation.

Conference presentation

IOCCC (1988) International Witches' Broom Project. At 10th International Cocoa Research Conference, Santo Domingo, Dominican Republic : Poster Paper (in press).